Spawning and Annual Fecundity of the Red Snapper (*Lutjanus campechanus*) from the Northeastern Gulf of Mexico

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COLLINS, L.A., A.G. JOHNSON and C.P. KEIM. 1996. Spawning and annual fecundity of the red snapper *(Lutjanus campechanus)* from the northeastern Gulf of Mexico [*Desove y fecundidad anual del pargo del Golfo (Lutjanus campechanus) del noreste del Golfo de México*], p. 174-188. *In* F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos and D. Pauly (eds.) Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conf. Proc. 48, 449 p.

Abstract

We used batch fecundity and spawning frequency methods to provide information on spawning and annual fecundity for the red snapper *(Lutjanus campechanus)*, an indeterminate spawner. These estimates were based on 923 females sampled during February 1991 through November 1993, from northwest Florida landings. Spawning occurred from May through September or early October. Oocytes >0.16 mm in diameter were homogeneously distributed in hydrated ovaries. The smallest (349 mm total length (TL) and 0.60 kg total weight (TW)) female contained 458 hydrated oocytes, while the largest (820 mm TL and 9.00 kg TW) and oldest (age 12 years) female contained 1 704 736 hydrated oocytes. Batch fecundity was predicted well by age (r^2=0.642) and TL (r^2=0.584). Estimates of the spawning frequency were 26 in 1991, 21 in 1992, and 35 in 1993. Estimates of annual fecundity ranged from 0.012 to 59.666 million per female, assuming that spawning frequency was constant for all sizes/ages. However, estimates of spawning frequency by age for n>11 suggested that age 8 females spawn more often than age 3, 4, 5 and 6 females. Previous estimates of annual fecundity (based on number of oocytes ≥0.20 mm in diameter) were strongly correlated with improved estimates incorporating batch fecundity and spawning frequency methods (based on number of hydrated oocytes). This relationship was described by the equation: improved annual fecundity estimate = (5.401·previous annual fecundity estimate)+ $2.054 \cdot 10^5$ (r^2 = 0.956; n = 21; TL range from 349 to 810 mm). This equation will allow adjustment of previous fecundity estimates, making previous spawning potential ratios more accurate and useful.

Resumen

El presente trabajo tiene por objeto proporcionar información sobre desove y fecundidad anual del pargo del Golfo (Lutjanus campechanus) *utilizando un método de pulsos de fecundidad y un método de frecuencia de desove. Estas estimaciones fueron basadas en 923 hembras muestreadas en el período de Febrero 1991 hasta Noviembre de 1993, de desembarques al noroeste de Florida. Los desoves ocurrieron* *de Mayo a Septiembre-inicio de Octubre. Los oocitos mayores de 0.16 mm de diámetro estaban homogéneamente distribuídos en ovarios hidratados. Las hembras más pequeñas (349 mm de longitud total (LT) y 0.60 kg de peso total (PT)) presentaron 458 oocitos hidratados, mientras que las hembras más grandes (820 mm LT y 9.0 kg PT) y más viejas (12 años de edad) presentaron 1 704 736 oocitos hidratados. Las estimaciones de frecuencia de desove fueron 26 en 1991; 21 en 1992 y 35 en 1993. Las estimaciones de fecundidad anual variaron de 0.012 a 59.666 millones por hembra, suponiendo que la frecuencia de desove fué constante para todas las tallas/edades. Sin embargo, la frecuencia de desove por edad sugiere que las hembras de 8 años de edad desovan más a menudo que las hembras de edades 3, 4, 5 y 6 años. Estimaciones previas de fecundidad anual (basada en el número de oocitos (≥0.20 mm de diámetro) fueron fuertemente correlacionadas con las estimaciones mejoradas incorporando los métodos de fecundidad por pulsos y frecuencia de desove (basados en el número de oocitos hidratados). Esta relación fué descrita por la ecuación: estimación mejorada de la fecundidad anual = (5.401·estimacion previa de la fecunidad anual) + 2.054·10*^{5} *(*r^2*=0.956; n=21; LT variando de 349 a 810 mm). Esta ecuación permitirá ajustar las estimaciones previas de fecundidad, haciendo que las relaciones de desove sean más precisas y útiles.*

Introduction

The red snapper (*Lutjanus campechanus*) is one of many valuable marine fish species of the southeastern United States for which there is inadequate information on reproduction. Information on spawning and annual fecundity are needed to assess the status of stocks. Minimum target level spawning potential ratios (SPRs) are used to assure maintenance of an adequate spawning stock. Accurate estimation of SPR requires the number of spawns per year by age (GMFMC 1989). Fecundity and sexual maturity estimates are important in population dynamics (Hunter et al. 1992). Age/size at maturity and spawning are other aspects of reproduction that are useful for management.

Red snapper occur only along the continental shelf of the Atlantic coast of the US and the Gulf of Mexico (Briggs 1958). Commercial landings of red snapper in the US have been generally declining since 1983 and a closure of this fishery occurred in 1991, 1992 and 1993 (Bennett 1993).

Although estimates of fecundity for red snapper have been developed (Collins et al. unpubl.) and published (Grimes 1987), their accuracy is now questionable given recent developments in methods of estimating batch fecundity and spawning frequency (Hunter et al. 1985; Hunter and Macewicz 1985). However, these previous estimates were considered to be the best available (Nelson 1988) and were used for red snapper stock assessment (Goodyear and Phares 1990).

This paper provides the first estimates of red snapper annual fecundity using batch fecundity/spawning frequency methods. Information on sex ratio, spawning frequency by age, and length/age at spawning is also given. In addition, an analysis of the relationship between previous and improved estimates provides a means to judge the accuracy of past SPRs, calculated using previous estimates of fecundity, as well as a formula for adjusting those estimates.

Methods

Red snapper were sampled mainly from recreational and commercial landings in Panama City, Florida. Fork length (FL) and total length (TL) were measured to the nearest cm or mm, and total wet weight (TW) was usually taken to the nearest 0.01 kg for each fish sampled. Gonads were removed and placed dry into plastic bags and stored on ice. Also, a sagittal otolith was removed and stored dry for ageing.

Gonads were processed as soon as possible in the laboratory. Excess tissue was removed and a small sample of each gonad was microscopically examined before preservation. Preliminary sex and maturation stage were assigned, and a maximum oocyte diameter recorded for females in order to compare these data with those from histology. Gonad weight was recorded to the nearest 0.1 g before selected gonads were preserved in a plastic bag with 5-10 times the gonad's volume of 10% buffered histological grade formalin. Large gonads were usually cut longitudinally to promote preservation.

We tested for homogeneity of oocyte diameter distributions throughout the ovary with the Kolmogorov-Smirnov test (Sokal and Rohlf 1981). This was done to allow selection of a single sample within an ovary for accurate determination of maturation stage and batch fecundity. Three late-stage ovaries were divided into 6 regions and a wedge-shaped sample was cut out in cross section to represent the periphery and center of each region. We teased apart all oocytes in each sample and measured the diameter of 300+ randomly selected oocytes in each region.

We also tested for differences in hydrated oocyte counts among regions and between lobes with an analysis of variance (SAS 1988). Six hydrated ovaries were divided into 6 regions and wedge-shaped samples taken as above.

A simple gonadosomatic index (GSI = (gonad weight/total weight) x 100) was used to generally delineate the spawning season by month. We also looked for relationships between length and GSI, since they are usually related allometrically (deVlaming et al. 1982).

Late-stage ovaries selected from the microscopic examination of fresh, whole oocyte samples were prepared for final sexing and staging through histology. Histological preparation (after the selected ovaries had been fixed in formalin for at least 2 weeks) was identical to that described by Fitzhugh et al. (1993). Ovarian stage judged from the most advanced stage of oocytes recorded from both the fresh material and histological slides was: 1-primary growth, 2-cortical alveolar, 3-vitellogenic, and 4-hydrated (Wallace and Selman 1981) and 5-spent (West 1990). Only Stage 4 ovaries, with no postovulatory follicles, were selected for fecundity estimation.

Ovaries selected for fecundity estimation were randomly sampled as follows. A wedge-shaped sample representing the periphery and center of each ovary in cross sections was weighed to the nearest 0.001 g and placed in a 2 dram vial with 33% glycerol. Sample size was usually 0.1-0.3 g. After at least 2 hours, the hydrated oocytes within the sample were carefully separated with teasing needles. We made at least two independent counts of all hydrated oocytes on each selected sample and used the mean as the final estimate. The batch fecundity estimate (BFE) was calculated gravimetrically, by multiplying the final estimate of the number of hydrated oocytes by the weight of the whole ovary, then dividing this product by the sample weight. Batch fecundity was regressed on TL, TW and age for all hydrated ovaries (SAS 1988).

The spawning frequency estimate (SFE), required for calculating annual fecundity (Hunter and Macewicz 1985), was found by dividing the duration of the spawning season (DOSS) in days by the number of days between spawning for all females. DOSS was the number of days between the first and last occurrence of hydrated oocytes or postovulatory follicles each year. The number of days between spawning for all females (≥TL of the smallest hydrated fish) was 100% divided by the percentage of hydrated females. SFE is the number of times that the species spawned each year.

Age was determined from sections of sagittal otoliths following the method of Johnson (1983). Nelson (1980) validated rings on red snapper otoliths as annular marks.

Spawning frequency by age was estimated using 1993 females ≥TL of the smallest hydrated female. As with the SFE, only females collected during the spawning season were included for this estimate.

The relationship between previous and improved annual fecundity estimates was determined. Previous estimates were represented by counts of all yolked oocytes (≥0.20 mm) from some of the same ovaries from which improved estimates were made. The previous method's formula was annual fecundity = (number of oocytes ≥0.20 mm x ovary weight)/sample weight. To determine the relationship between the two estimates of fecundity, we regressed the improved estimate on the previous estimate using SAS (1988).

Results

A total of 1 475 red snapper gonads were sampled from northwest Florida waters during February 1991 through November 1993. Most fish came from charterboats during the summer months. The largest portion of fish (629, or 43%) was collected in 1993 when we sampled almost daily most of the summer, while 484 (33%) were sampled in 1992, and 362 (24%) in 1991. Sampling in 1991 was biased toward females, but unbiased sampling in 1992 and 1993 showed 59% and 50% females, respectively.

Most fish were caught, iced, landed and sampled the same day, which allowed adequate preservation of gonads. Preservation of gonads in formalin usually occurred within 12 to 48 hours of the fish's death.

Red snapper spawned serially from May-June through September-early October, according to GSIs (Fig. 1 and Tables 1 and 2). Peaks of spawning apparently occurred in June, July and August. Monthly mean-GSIs were similar in each of the 3 years, except for females in June 1993, when the estimate was much higher than the 1991 and 1992 values. The greater mean GSI in June 1993 was explained by the fact that significantly larger females were sampled in June 1993 (mean TL = 528 mm) than in June 1991 (mean TL = 389 mm) and June 1992 (mean TL = 433 mm).

Examinations of gonads revealed that red snappers are gonochorists. The lobes of the ovaries and testes were symmetrical. Large amounts of adipose tissue were usually attached to both ovaries and testes.

The test for homogeneity of oocyte diameter distributions throughout each of 3 hydrated ovaries showed no significant differences for oocytes >0.16 mm in diameter (Tables 3 and 4). This result allowed

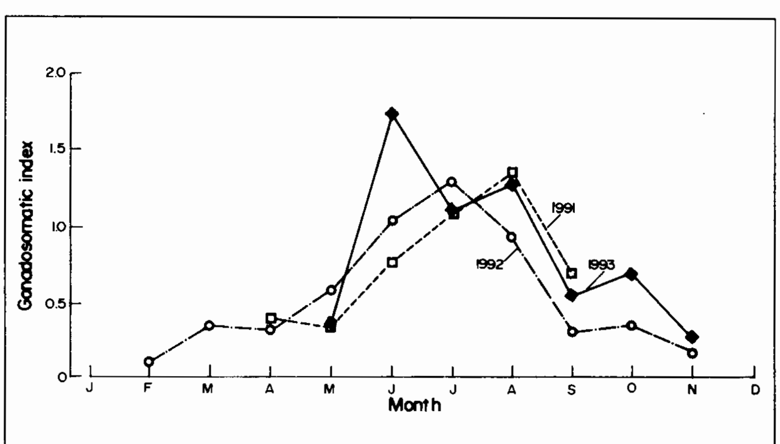

Fig. 1. Mean GSI of female red snapper from the NE Gulf of Mexico, 1991-1993. N = 646 (months with n > 10). ***[Índice gonadosomático (GSI) medio de hembras de pargo del Golfo del noreste del Golfo de México, 1991-1993. N = 646; meses con n > 10.]***

Table 1. Gonosomatic index (GSI) and total length (TL in mm) for female red snapper by month, 1991-1993; s.d. = standard deviation, c.v. = coefficient of variation, N = number of individuals. [*Indice gonadosomático (GSI) y longitud total (TL, en mm) para hembras de pargo del Golfo, por mes, durante 1991-1993; s.d.= deviación estandar; c.v.= coeficiente de variación, N = numero de individuos.*]

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	N
1991												
n	0	1	8	35	39	16	24	24	10	6	5	168
Min GSI	-	1.09	0.13	0.03	0.04	0.11	0.10	0.09	0.07	0.15	0.10	
Max GSI	-	1.09	0.93	1.77	4.21	3.69	2.71	3.13	2.03	0.59	0.81	
Mean GSI	-	1.09	0.43	0.39	0.34	0.78	1.09	1.36	0.71	0.35	0.35	
s.d.	-	-	0.26	0.29	0.67	1.00	0.90	0.87	0.75	0.15	0.28	
c.v.	-	-	59.12	74.36	199.39	128.41	82.12	64.25	106.10	43.46	82.41	
Min TL	-	795	460	350	330	340	350	350	305	355	357	
Max TL	-	795	710	670	740	550	560	640	550	630	580	
Mean TL	-	795	567	460	454	389	462	482	436	484	469	
s.d.	-	-	87.05	61.72	81.27	67.77	57.38	66.18	73.88	94.47	83.77	
c.v.	-	-	15.36	13.42	17.89	17.41	12.43	13.74	16.96	19.51	17.85	
1992												
n	0	10	17	16	16	22	25	33	32	12	26	209
Min GSI	-	0.04	0.10	0.09	0.07	0.03	0.19	0.14	0.11	0.18	0.03	
Max GSI	-	0.26	0.55	0.75	2.25	2.93	3.41	2.62	2.37	0.78	0.72	
Mean GSI	-	0.11	0.34	0.31	0.59	1.04	1.29	0.94	0.31	0.36	0.18	
s.d.	-	0.06	0.15	0.18	0.62	0.91	1.01	0.77	0.40	0.18	0.15	
c.v.	-	57.49	42.55	57.94	105.50	87.75	78.05	82.12	128.80	51.63	83.82	
Min TL	-	359	336	366	355	331	358	342	359	393	336	
Max TL	-	638	730	654	607	785	810	736	651	709	662	
Mean TL	-	427	546	497	429	433	469	497	444	516	433	
s.d.	-	79.83	109.11	90.91	79.74	114.37	116.62	114.28	63.72	114.53	77.44	
c.v.	-	18.69	19.98	18.30	18.59	26.44	24.85	22.97	14.35	22.18	17.88	
1993												
n	2	0	3	7	39	44	57	40	56	31	19	298
Min GSI	0.14	-	0.29	0.20	0.07	0.04	0.08	0.19	0.07	0.14	0.06	
Max GSI	0.43	-	0.60	0.34	2.05	10.09	4.83	7.21	2.41	2.08	0.61	
Mean GSI	0.29	-	0.43	0.27	0.36	1.74	1.11	1.28	0.56	0.71	0.28	
s.d.	0.21	-	0.16	0.05	0.40	2.17	1.20	1.52	0.57	0.42	0.17	
c.v.	72.62	-	36.37	18.06	109.76	125.17	108.89	119.17	100.49	58.44	62.20	
Min TL	455	-	431	372	334	320	326	345	335	366	325	
Max TL	710	-	575	715	642	869	852	750	744	741	692	
Mean TL	583	-	506	464	431	528	477	469	463	543	474	
s.d.	180.31	-	72.19	114.23	68.08	141.43	140.24	94.26	94.19	109.69	93.76	
c.v.	30.96	-	14.27	24.64	15.81	26.78	29.40	20.10	20.33	20.21	84.73	
1991-93N	2	11	28	58	94	82	106	97	98	49	50	675

Table 2. Gonadosomatic index (GSI) and total length (TL in mm) for male red snapper by month, 1991-1993; s.d. = standard deviation, c.v. = coefficient of variation, N = number of individuals. [*Indice gonadosomático (GSI) y longitud total (TL, en mm) para machos de pargo del Golfo, por mes durante 1991-1993, s.d. = deviación estándar; c.v. = coeficiente de variación, N = numero de individuos.*]

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	N
1991												
n	0	0	1	14	1	0	0	0	0	0	0	16
Min GSI	-	-	0.17	0.04	0.26	-	-	-	-	-	-	
Max GSI	-	-	0.17	0.51	0.26	-	-	-	-	-	-	
Mean GSI	-	-	0.17	0.19	0.26	-	-	-	-	-	-	
s.d.	-	-	-	0.17	-	-	-	-	-	-	-	
c.v.	-	-	-	88.90	-	-	-	-				
Min TL	-	-	630	386	440	-	-	-	-	-	-	
Max TL	-	-	630	570	440	-	-	-	-	-	-	
Mean TL	-	-	630	454	440	-	-	-	-	-	-	
s.d.	-	-	-	44.06	-	-	-	-	-	-	-	
c.v.	-	-	-	9.71	-	-	-	-	-	-	-	
1992												
n	0	1	3	1	13	21	22	15	26	8	7	117
Min GSI	-	0.04	0.09	0.70	0.02	0.02	0.05	0.05	0.04	0.03	0.02	
Max GSI	-	0.04	0.22	0.70	1.33	3.81	1.86	1.65	1.20	0.40	0.10	
Mean GSI	-	0.04	0.17	0.70	0.43	0.56	0.48	0.41	0.24	0.15	0.06	
s.d.	-	-	0.07	-	0.43	0.88	0.49	0.44	0.27	0.13	0.03	
c.v.	-	-	43.26	-	101.23	158.11	101.46	108.78	110.62	85.07	52.79	
Min TL	-	652	406	733	332	330	345	365	342	306	354	
Max TL	-	652	574	733	702	750	780	709	590	735	448	
Mean TL	-	652	504	733	513	466	430	491	461	581	418	
s.d.	-	-	87.43	-	129.55	110.79	99.69	111.12	60.71	152.47	35.88	
c.v.	-	-	17.35	-	25.25	23.79	23.16	22.64	13.16	26.24	8.58	
1993												
n	3	1	1	3	25	33	59	59	47	46	16	293
Min GSI	0.03	0.04	0.05	0.03	0.03	0.05	0.03	0.04	0.06	0.04	0.05	
Max GSI	0.23	0.04	0.05	0.09	0.61	3.17	4.46	3.91	2.77	1.35	0.24	
Mean GSI	0.15	0.04	0.05	0.06	0.18	0.60	0.63	0.57	0.63	0.53	0.11	
s.d.	0.11	-	-	0.03	0.15	0.75	0.85	0.67	0.75	0.32	0.06	
c.v.	71.01	-	-	46.11	85.24	124.02	135.23	116.84	118.26	61.04	55.65	
Min TL	515	790	511	358	350	350	316	336	327	247	345	
Max TL	703	790	511	478	700	792	744	676	695	870	592	
Mean TL	593	790	511	423	464	479	453	463	465	510	484	
s.d.	98.17	-	-	60.71	77.97	92.13	106.83	94.43	93.60	132.94	74.89	
c.v.	16.56	-	-	14.34	16.80	19.23	23.57	20.40	20.15	26.06	15.47	
1991-93 N	3	2	5	18	39	54	81	74	73	54	23	426

us to sample just one location on each ovary to determine maturation stages and maximum oocyte diameter.

Hydrated oocyte counts per unit of weight did not differ significantly by region or lobe (Table 5). The 6 ovaries selected for this ANOVA represented June through October, 1993.

Percentage frequencies of 588 Stage 1-4 ovaries (unpreserved, examined microscopically) varied by month (Fig. 2 and Table 6) and basically showed the same spawning peaks as had GSI. Stage 1-2 ovaries were prominent in January through May, and November. Stage 3 ovaries were found from May through November. Stage 4 ovaries occurred from May through September or October, but were most prominent in June through September.

Means of maximum oocyte diameter for 576 ovaries indicated that spawning occurred from June through October (Fig. 3 and Table 6). Greatest means of maximum oocyte diameter were 0.51, 0.67 and 0.55 in June, July and August of 1992, respectively.

A total of 237 Stage 3-4 ovaries was examined histologically from red snapper collected during the period May 1991 through October 1993. Physical appearance of Stage 1-4 oocytes was identical to those of sheepshead described and illustrated by Render and Wilson (1992). Only one ovary with fresh postovulatory follicles was found, in June 1992. Sixty-six ovaries weighing 1.2 to 908 g were hydrated and intact, and thus were used for BFEs (Table 7). These BFE fish were 349 to 820 mm TL, 0.60 to 9.10 kg TW and, age 3 to 12 years old. Early stage hydrated (including yolk coalescence) and late stage hydrated oocytes were included in Stage 4 ovaries used for BFEs. Atresia of yolked oocytes occurred in many Stage 4 ovaries; this may have been an effect of delayed preservation.

Batch fecundity estimates (BFEs) ranged from 458 to 1 704 736, for the smallest and largest fish, respectively (Table 7). BFEs by year were not significantly different ($F = 1.43$, $p = 0.237$), therefore data for all years were combined for analysis. TL, TW and age all proved to be useful predictors of batch fecundity, with simple linear models providing the best fits. These relationships were described by the following equations:

$$BFE = (1.949 \times 10^3(TL)) - 8.055 \times 10^5 \quad (r^2 = 0.584);$$

$$BFE = (1.363 \times 10^5(TW)) - 1.315 \times 10^5 \quad (r^2 = 0.741); \text{ and}$$

$$BFE = (1.278 \times 10^5(AGE)) - 4.375 \times 10^5 \quad (r^2 = 0.642);$$

with TL in mm, TW in kg and age in years.

SFEs per year ranged from 21 to 35 (Table 7). The smallest hydrated females were 400, 362 and 344 mm TL in 1991, 1992 and 1993, respectively. Percentage of hydrated females was 25.2, 16.8 and 22.7 in 1991, 1992 and 1993, respectively. Days between spawning were 3.97, 5.95 and 4.41 in 1991, 1992 and 1993, respectively. DOSS was 102, 119 and 154 in 1991, 1992 and 1993, respectively. All estimates for 1993 are probably the most accurate because of the greater sampling intensity during that year.

Annual fecundity estimates ranged from 11 613 to 59 665 760 assuming that SFE was the same for all females by year (Table 7). Again, 1993 estimates are probably the most accurate.

We aged 502 of 526 red snapper of both sexes collected in 1993. The remaining fish had confusing marks.

Estimates of SFE by age were made with all aged females ≥344 mm TL collected from 2 May through 3 October 1993 (Table 8). A comparison of samples with $n > 10$ was possible for only ages 3, 4, 5, 6, and 8. The SFE for ages 3, 4, 5, and 6 were 28, 30, 41 and 14, respectively. The SFE for age 8 was 112. Sample size was much greater for ages 3-5 ($n>43$) than for age 6 and 8 ($n = 11$), however.

The relationship between AFEs using previous (Collins et al., unpubl.) and improved (Hunter et al. 1985) methods was determined

Table 3. Oocyte diameter frequency distributions by region of red snapper for two fully hydrated ovaries (I and II) and one partially hydrated ovary (III). Oocyte diameter given as ocular micrometer units (OMU = 0.04 mm). [***Distribución de frecuencia del diámetro de los oocitos por región de ovarios de pargo del Golfo para dos ovarios totalmente hidratados (I y II), y un ovario parcialmente hidratado (III). El diámetro de los oocitos está dado en unidades de micrómetro ocular (OMU). (Un OMU=0.04 mm).***]

	I						II						III					
OMU	A[a]	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1	69	73	79	65	82	69	82	72	73	59	102	67	51	93	93	101	105	57
2	127	104	99	117	101	97	83	100	101	98	102	78	66	51	66	97	64	91
3	43	45	43	61	60	40	36	22	31	34	22	25	81	64	60	53	60	24
4	10	21	21	21	18	12	17	8	14	14	9	16	30	50	32	16	19	9
5	14	10	9	8	14	17	16	9	15	16	9	10	31	15	5	10	7	4
6	5	10	5	12	7	10	14	10	18	9	8	10	3	6	6	5	8	5
7	12	8	2	2	13	6	12	14	12	11	8	17	9	4	4	2	2	9
8	9	2	3	1	6	7	22	28	17	11	13	21	4	4	4	3	2	14
9	12	2	9	8	2	6	12	17	8	14	14	14	5	1	4	5	4	12
10	12	4	12	2	6	17	4	16	16	3	10	11	12	1	7	3	7	21
11	9	6	5	3	7	6	9	4	8	5	4	18	4	7	8	3	9	25
12	3	1	3	2	3	1	4	8	4	3	3	3	10	1	8	3	10	21
13	1	0	1	1	0	1	4	5	0	0	1	3	3	2	3	0	2	6
14	0	0	1	0	0	1	4	5	5	3	1	2	0	0	0	0	1	2
15	0	0	1	0	1	0	12	11	14	8	9	16	0	0	0	0	0	0
16	0	0	2	0	1	0	4	10	10	7	4	9	0	0	0	0	0	0
17	1	3	2	0	0	2	6	13	7	9	9	9	0	1	0	0	0	0
18	3	1	0	2	2	1	2	4	2	9	8	2	0	0	0	0	0	0
19	4	3	3	5	3	3	1	3	5	1	2	2	0	0	0	0	0	0
20	5	2	2	6	7	2	0	0	0	0	0	2	0	0	0	0	0	0
21	6	2	1	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0
22	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total[b]	347	301	305	318	336	300	344	359	360	314	338	335	309	300	300	301	300	300

[a] Ovary regions:
A = right lobe, anterior one-third
B = right lobe, middle one-third
C = right lobe, posterior one-third
D = left lobe, anterior one-third
E = left lobe, middle one-third
F = left lobe, posterior one-third

[b] Number of oocytes sampled.

Table 4. Regions of three red snapper ovaries where significantly different oocyte diameter frequencies were found by the Kolmogorov-Smirnov test. See previous table for location of regions. One OMU = 0.04 mm. [***Regiones de tres ovarios de pargo del Golfo donde se encontraron diferencias significativas en la frecuencia del diámetro de los oocitos, al aplicar la prueba de Kolmogorov-Smirnov. Ver tabla anterior para localización de las regiones. Un OMU= 0.04 mm.***]

OMU	I (fully-hydrated)	II (fully-hydrated)	III (partially-hydrated)		
				$d_{0.05}$	d
1	None	D vs E	A vs B	0.1103	0.1450
-	-	($d^{0.05}$ = 0.1064,	A vs C	0.1103	0.1450
-	-	d = 0.1139)	A vs D	0.1100	0.1705
-	-	-	A vs E	0.1034	0.1850
-	-	-	C vs F	0.1103	0.1200
-	-	-	D vs F	0.1108	0.1455
-	-	-	E vs F	0.1103	0.1600
2	None	None	B vs D	0.1108	0.1523
3	None	None	A vs F	0.1103	0.1821
-	-		C vs F	0.1103	0.1200
4	None	None	B vs F	0.1103	0.1367
5-27	None	None	None	-	-

Table 5. Effect of location of red snapper tissue samples for hydrated oocyte counts per unit of weight (g). Locations are anterior (1), middle (2), and posterior (3) of ovarian lobes. Analysis of variance indicates significance of location within a lobe for number of hydrated oocytes per gram of tissue. [***Efecto de la localización de las muestras del tejido del pargo del Golfo para conteo de oocitos hidratados por unidad de peso (g). Las localizaciones fueron anterior (1), media (2), y posterior (3) de los lóbulos ováricos. El análisis de varianza indica significancia de localización dentro de un lóbulo para el número de oocitos hidratados por gramo de tejido.***]

Positions of sample in ovary	Mean number and standard deviation of oocytes per gram of ovarian tissue								
	Lobe 1			Lobe 2			Both lobes		
	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n
1	2 333	767	6	2 427	792	6	2 380	745	12
2	2 357	887	6	2 454	942	6	2 405	874	12
3	2 423	856	6	2 387	782	6	2 405	782	12
Total	2 371	788	18	2 423	791	18	2 379	779	(36)

ANOVA of oocytes/gram of ovarian tissue.

Source	df	SS	MS	F	PR>F
Lobe 1 vs 2	1	23 883.54	23 883.54	0.04	0.85
Region	11	3 616.64	3 616.64	0.01	0.94
Interaction	1	25 206.79	25 206.79	0.04	0.85
Error	32	21 173 908.34	661 684.84	-	-
Total	35	21 226 615.31	-	-	-

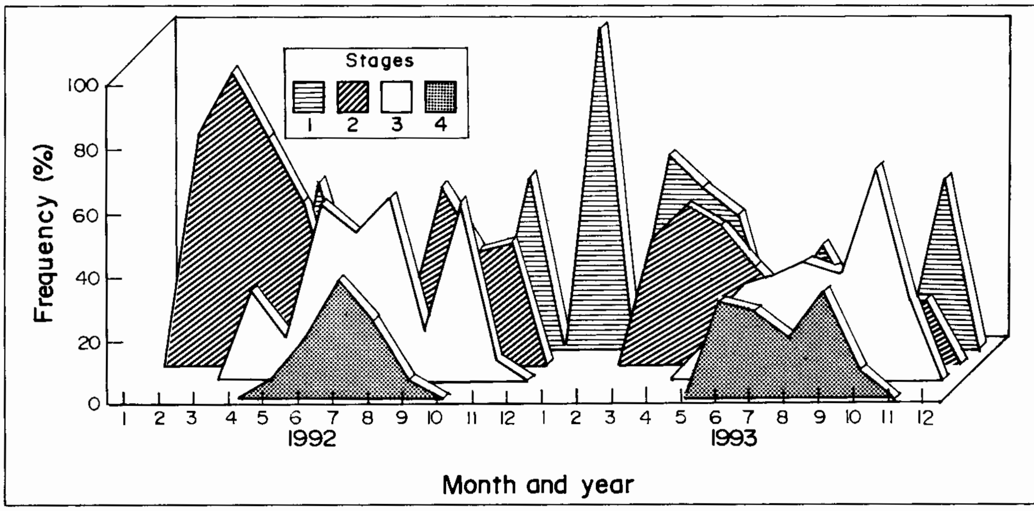

Fig. 2. Percentage frequency of red snapper ovary stages, 1992 (N=275) and 1993 (N=313). [***Frecuencia porcentual de los diferentes estadíos de desarrollo de los ovarios de pargo del Golfo, 1992 (N=275) y 1993 (N=313).***]

Table 6. Relative frequency in % of female red snapper by maturation stage and maximum oocyte diameter from microscopic examination of unpreserved, whole oocytes by month for 1992 and 1993. [***Frecuencia porcentual del estado de maduración de hembras, y diámetro máximo del oocito, del exámen microscópico de oocitos completos sin preservar, por mes, para 1992 y 1993.***]

Month/year		Stage 1	2	3	4	N	Maximum oocyte diameter $\bar{x}$	s.d.	N
Jan	'92	-	-	-	-	0	-	-	0
	'93	100	0	0	0	2	0.12	0	2
Feb	'92	27	73	0	0	33	0.18	0.08	31
	'93	-	-	-	-	0	-	-	0
Mar	'92	8	92	0	0	24	0.13	0.06	21
	'93	60	40	0	0	5	0.22	0.13	5
Apr	'92	0	71	29	0	17	0.25	0.17	15
	'93	50	50	0	0	8	0.15	0.05	8
May	'92	29	52	14	5	21	0.29	0.18	21
	'93	42	44	12	2	43	0.22	0.20	42
Jun	'92	6	19	56	19	32	0.51	0.21	32
	'93	9	31	29	31	45	0.48	0.27	44
Jul	'92	0	15	47	38	34	0.67	0.20	33
	'93	18	22	32	28	60	0.47	0.23	60
Aug	'92	3	14	58	25	36	0.55	0.18	36
	93	5	38	38	19	42	0.41	0.21	42
Sep	'92	22	56	17	6	36	0.31	0.23	36
	'93	14	18	34	34	56	0.45	0.25	56
Oct	'92	7	36	57	0	14	0.38	0.21	13
	'93	6	18	67	9	33	0.47	0.21	33
Nov	'92	54	39	7	0	28	0.15	0.11	27
	'93	53	21	26	0	19	0.22	0.20	19
Dec	'92	-	-	-	-	0	-	-	0
	'93	-	-	-	-	0	-	-	0
All	'92	16	44	28	12	275	-	-	265
	'93	20	28	31	20	313	-	-	311

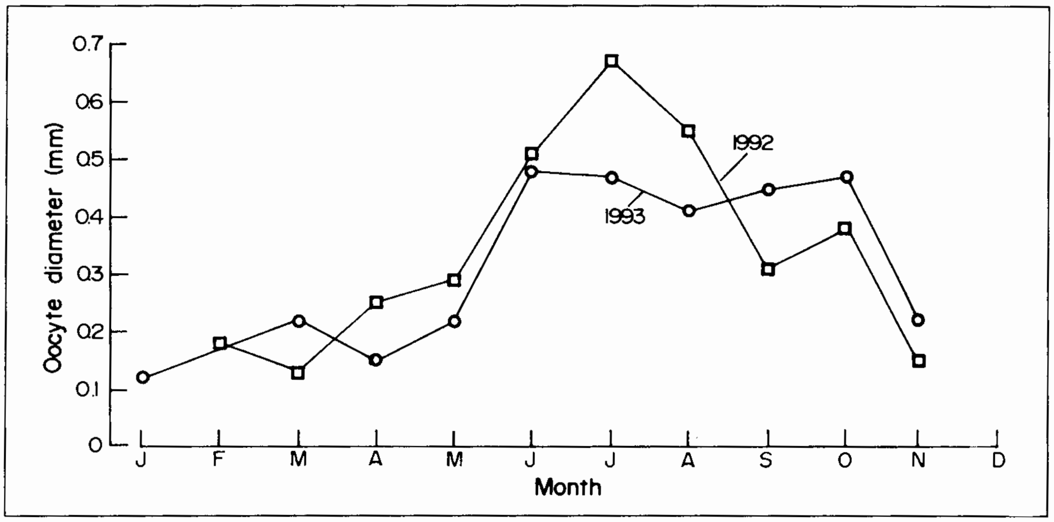

Fig. 3. Mean maximum oocyte diameter of red snapper, 1992 (N=265) and 1993 (N=311). [***Diámetro máximo promedio (en mm) de los oocitos del pargo del Golfo, 1992 (N=265) y 1993 (N=311).***]

from 21 fish from 349 to 810 mm TL (Table 9). This relationship was: Improved AFE = (5.401•previous AFE)+ 2.054•10^5 (r^2 = 0.956). Since previous AFEs are strongly correlated to improved AFEs, adjustments can now be made on previous AFEs to improve stock assessments. However, an assumption of no significant difference in AFE between years would have to be made in order to make these adjustments to previous years' AFEs.

Discussion and Recommendations

Dockside sampling of charterboat catches provided an adequate first measurement of red snapper spawning and annual fecundity off northwest Florida. The delay in preserving gonads was necessary because of the need to examine unpreserved material (to inspect and measure the oocytes before they were affected by formalin), and the fact that periodic backups in processing occurred with our intensive sampling.

Intensive sampling at sea with rapid examination and preservation of ovaries is needed to identify spawning time and better define rates of ovarian development and atresia for red snapper. This species probably spawns at night (Grimes 1987; B. Thompson, pers. comm.), which could explain why ovaries in our collections used for BFE had both early and late hydration. The charterboats usually fished throughout the day and landed their catch in the late afternoon. Spawning of red snapper may occur in the early evening off northwest Florida, since more than half of the ovaries used for BFE were late-stage hydrated. Post-ovulatory follicles apparently deteriorated rapidly after spawning.

Studies are also needed on large numbers of large, old snappers to better estimate annual fecundity and frequency of spawning. Fish of this greater size are not common off northwest Florida, but are relatively common off Louisiana.

Acknowledgements

We thank many individuals in the Panama City, Florida, area for allowing us to sample their catch, in particular commercial Captains Sigurd Smeby, Mark Raffield, Mike

Table 7. Data used for red snapper annual fecundity estimates (AFEs), 1991-1993. [***Datos usados para la estimación de fecundidad anual del pargo del Golfo (AFEs), 1991-1993.***]

Date dd/mm/yy	Length TL (mm)	Weight (kg)	Age (years)	Ovary weight (g)	Counts of hydrated oocytes			BFE	SFE	AFE
					n	mean	s.d.			
19/06/91	420	2.10	4	35.7	3	1 238	76	155 622	26	4 046 172
06/07/91	440	1.30	5	32.9	5	546	49	117 408	26	3 052 608
14/07/91	470	1.40	4	32.8	3	330	57	82 000	26	2 132 000
26/07/91	450	1.10	3	28.6	3	469	117	74 107	26	1 926 782
04/08/91	440	1.40	4	28.9	3	640	55	117 809	26	3 063 034
04/08/91	470	1.70	5	24.5	4	539	177	83 053	26	2 159 378
09/08/91	400	1.10	3	3.9	3	31	16	1 950	26	50 700
09/08/91	470	1.50	3	18.1	3	683	40	75 380	26	1 959 880
09/08/91	480	1.60	5	50.0	3	950	62	165 505	26	4 303 130
07/09/91	420	1.00	3	33.1	3	484	35	103 357	26	2 687 282
28/05/92	418	0.84	-	5.4	3	50	16	8 710	21	182 910
11/06/92	525	2.00	-	131.4	3	497	64	349 229	21	7 333 809
15/06/92	580	3.10	4	150.8	2	1 834	26	397 938	21	8 356 698
20/06/92	362	0.70	3	4.5	3	79	11	10 456	21	219 576
27/06/92	665	4.65	8	72.2	3	325	46	153 366	21	3 220 686
09/07/92	475	1.70	4	43.5	3	743	95	176 615	21	3 708 915
11/07/92	380	-	-	4.0	3	29	21	1 902	21	39 942
18/07/92	475	1.22	4	33.2	3	652	55	117 643	21	2 470 503
18/07/92	431	1.04	4	27.1	3	557	41	75 098	21	1 577 058
18/07/92	810	8.85	9	302.1	5	468	42	817 242	21	17 162 082
19/07/92	606	2.90	5	60.0	2	1 516	86	236 875	21	4 974 375
01/08/92	362	0.80	3	4.1	3	45	1	5 766	21	121 086
12/09/92	651	3.88	6	92.1	3	734	62	254 141	21	5 336 961
23/09/92	426	1.25	5	4.9	3	7	2	553	21	11 613
15/06/93	692	5.00	8	180.0	2	1 067	61	741 544	35	25 954 040
15/06/93	718	5.50	-	197.7	2	743	21	676 918	35	23 692 130
15/06/93	820	9.00	12	908.2	3	687	57	1 704 736	35	59 665 760
22/06/93	435	1.30	3	22.7	2	773	14	74 669	35	2 613 415
22/06/93	445	1.30	5	18.5	2	578	30	70 349	35	2 462 215
23/06/93	645	3.80	10	168.5	2	764	30	531 959	35	18 618 565
24/06/93	765	9.10	10	546.5	3	882	139	1 456 499	35	50 977 465
26/06/93	425	1.20	4	13.4	2	668	54	53 600	35	1 876 000
27/06/93	430	1.00	4	4.2	3	450	107	6 279	35	219 765
06/07/93	541	2.40	4	35.0	3	689	115	141 023	35	4 935 805
06/07/93	648	3.75	4	84.4	3	746	47	234 061	35	8 192 135
11/07/93	708	4.60	8	173.9	2	789	15	766 520	35	26 828 200
11/07/93	787	6.30	8	302.2	3	759	125	697 173	35	24 401 055
12/07/93	485	1.50	4	43.6	3	459	45	122 775	35	4 297 125
12/07/93	505	1.50	5	72.5	3	815	61	252 511	35	8 837 885
18/07/93	395	0.90	4	6.7	3	567	56	22 087	35	773 045
18/07/93	407	1.00	3	11.7	2	342	35	42 120	35	1 474 200
24/07/93	538	2.35	5	16.0	2	237	1	37 920	35	1 327 200
24/07/93	704	4.80	8	117.4	2	535	13	269 567	35	9 434 845
29/07/93	655	4.90	8	81.1	2	413	30	178 161	35	6 235 635
09/08/93	410	0.80	3	13.5	3	424	10	48 923	35	1 712 305
14/08/93	640	3.80	-	136.4	2	791	23	531 490	35	18 602 150
28/08/93	553	2.55	5	26.4	2	530	18	39 525	35	1 383 375
28/08/93	349	0.60	-	1.2	2	37	3	458	35	16 030
01/09/93	504	2.10	4	15.3	3	184	19	25 828	35	903 980
04/09/93	428	1.20	4	13.4	2	469	38	44 890	35	1 571 150
04/09/93	362	0.75	-	2.9	3	195	22	3 512	35	122 920
11/09/93	419	1.20	5	11.2	3	416	37	31 061	35	1 087 135
15/09/93	530	2.30	-	36.6	2	616	43	131 846	35	4 614 610
15/09/93	479	1.59	-	18.6	2	467	29	55 681	35	1 948 835
15/09/93	454	1.40	4	6.3	3	162	22	13 608	35	476 280
15/09/93	455	1.36	-	26.0	3	567	85	108 397	35	3 793 895
17/09/93	515	1.78	-	23.5	2	498	6	70 927	35	2 482445
18/09/93	413	1.05	4	4.6	3	120	13	5 633	35	197 155
21/09/93	744	4.90	6	118.1	2	523	1	383 642	35	13 427 470
25/09/93	370	0.60	-	7.1	2	409	14	22 338	35	781 830
25/09/93	456	1.30	4	3.4	2	82	0	1 991	35	69 685
29/09/93	376	0.70	3	3.6	2	283	16	10 396	35	363 860
01/10/93	615	3.50	5	38.2	2	256	27	72 979	35	2 554 265
01/10/93	540	2.30	4	30.5	3	198	27	45 067	35	1 577 345
01/10/93	408	1.10	3	6.3	2	203	18	12 662	35	443 170
03/10/93	705	5.00	8	23.1	2	42	1	10 002	35	350 070

Table 8. Spawning frequency estimates by age of female red snapper with hydrated oocytes from 2 May 1993 to 3 October 1993. [*Estimación de la frecuencia de desove por edad de las hembras mas pequeñas de pargo del Golfo con oocitos hidratados, de Mayo 2 de 1993 a Octubre 3 de 1993.*]

Age (years)	Length (TL; mm)	n	n with hydrated oocytes	Spawning frequency
2	344-389	4	1	39
3	345-470	44	10	35
4	344-734	76	15	30
5	350-618	45	12	41
6	456-744	11	1	14
7	646-750	2	0	0
8	530-852	11	7	98
9	755	1	0	0
10	645-765	2	2	154
11	-	0	-	-
12	820	1	1	154
13-24	-	0	-	-
25	869	1	0	0
2-25	344-869	198	51	40

Table 9. Data used for analyzing relationships of previous and improved annual fecundity estimates (AFEs) for red snapper. [*Datos usados para analizar las relaciones de las estimaciones de fecundidad anual, previa y mejorada (AFEs) para el pargo del Golfo.*]

Date (dd/mm/yy)	Length (TL; mm)	Weight (kg)	Age (years)	Mean count of oocytes ≥0.20 mm	Previous AFE	Mean count of hydrated oocytes	Improved AFE
19/06/91	420	2.10	4	4 965	654 919	1 238	4 046 172
26/07/91	450	1.10	3	3 023	486 200	469	1 926 782
04/08/91	440	1.40	4	2 342	453 564	640	3 063 034
11/06/92	525	2.00	-	3 183	2 147 371	497	7 333 809
27/06/92	665	4.65	8	1 875	1 073 090	325	3 220 686
18/07/92	810	8.85	9	2 327	4 332 428	468	17 162 082
01/08/92	362	0.80	3	487	60 347	45	121 086
12/09/92	651	3.88	6	4 009	1 465 290	734	5 336 961
23/09/92	426	1.25	5	301	27 898	7	11 613
15/06/93	820	9.00	12	4 807	8 166 356	687	59 665 760
23/06/93	645	3.80	10	3 510	2 519 145	764	18 618 565
24/06/93	765	9.10	10	4 585	7 914 966	882	50 977 465
06/07/93	541	2.40	4	2 936	691 333	689	4 935 805
24/07/93	538	2.35	5	1 373	242 560	237	1 327 200
28/08/93	349	0.60	-	1 311	17 035	37	16 030
28/08/93	553	2.55	5	3 780	340 814	530	1 383 375
21/09/93	744	4.90	6	2 257	1 742 158	523	13 427 470
25/09/93	370	0.60	-	1 326	82 578	409	781 830
25/09/93	456	1.30	4	1 359	37 181	82	69 685
01/10/93	615	3.50	5	1 051	397 109	256	2 554 265
03/10/93	705	5.00	8	992	250 052	42	350 070

Raffield, and Ray Ward. Jerry and Carl Anderson allowed us to routinely sample their seafood markets at Panama City Beach. Charterboat captains Bill Archer and Charles Paprocki also participated in our sampling. Special thanks are extended to National Marine Fisheries Service Fishery Reporting Specialist Debbie Fable, who routinely interrupted her schedule to assist our sampling.

Bruce Thompson, Cheryl Crowder and Jeff Render of Louisiana State University in Baton Rouge provided valuable advice on ovarian histology. Lew Bullock, Ron Taylor and Ruth Reece of the Florida Marine Research Institute in St. Petersburg helped with sampling methodology and histology.

Marc Remy, Sean Murray and James McClain processed gonads and participated in batch fecundity estimation. John Dahl assisted with efficient processing of otoliths.

This research was funded by the MARFIN (Marine Fisheries Initiative) Program of the NMFS, Southeast Region.

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Proceedings of an EPOMEX/ICLARM International Workshop
on Tropical Snappers and Groupers
held at the University of Campeche
Campeche, Mexico
26-29 October 1993

Edited by

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